Ask Dr. ALOHA:

Making "Conservative" Choices

Mark, a new recruit to the Belmont Fire Department’s hazmat team, is trying to build his air modeling skills by running practice scenarios in ALOHA. He has also been talking with community planners who are working with the Fire Department to prepare hazards analyses for facilities in Belmont. They use the method described in *Technical Guidance for Hazards Analysis*,[1] commonly called the “Green Book.” To identify the facilities that pose the greatest risk to Belmont, Mark found, you prepare a “credible worst-case scenario” for each facility. To do this, you choose the conditions for an accidental release of that chemical that would result in a vulnerable zone[2] that is as large as reasonably possible. When you make the simple calculations described in the Green Book (the same calculations made by CAMEO's Scenarios stack), specify worst case conditions by (a) using the maximum amount of chemical stored in a single vessel or in interconnected vessels as your estimate of the amount released, (b) choosing atmospheric stability class F, (c) setting wind speed equal to 3.4 miles per hour (1.5 meters per second), and (d) choosing Open Country ground roughness. Planners call these choices “conservative” because by using them, you are more likely to overestimate the vulnerable zone than to underestimate it.

Mark could see that it would be useful to recognize conservative choices for important ALOHA inputs, too. He already had found that the size of a footprint changed as he experimented with different values for certain model inputs, such as wind speed and ground roughness. He had also discovered that while these and other model inputs substantially influence ALOHA’s results, others have much less effect. He had learned from more experienced colleagues that it’s often possible to get only a rough estimate of some important inputs, such as the size of a hole in a tank wall. He wondered: If you estimate that wind speed is between 5 and 8 miles per hour, is 5 miles per hour always a more conservative value to use in ALOHA than 8 miles per hour, or vice versa?

Let's look at the factors that have the greatest influence on ALOHA footprint length or other important outputs, and discuss how to identify conservative choices for each one. These factors, and their effects on ALOHA’s footprint and concentration estimates, are shown in Table 1, below.

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[1]This handbook was prepared by the U. S. Environmental Protection Agency, the Federal Emergency Management Agency, and the U. S. Department of Transportation to provide direction to people required to perform the hazard analyses described in Title III of the Emergency Planning and Community Right-to-Know Act, also known as the Superfund Amendments and Reauthorization Act of 1986 (SARA).

[2]The vulnerable zone encompasses the area around the location of an accidental release where the airborne, ground-level concentration of chemical could reach a level above which there may be serious irreversible health effects or death caused by a single exposure for a relatively short time period.

Table 1. General effects of key input values on ALOHA output.

INCREASING:	CAUSES:	RESULTING IN:
Weather and Terrain:		
Wind speed	Faster cloud dilution	Shorter footprint
Atmospheric stability	Slower cloud dilution	Longer footprint
Ground roughness	Faster cloud dilution	Shorter footprint
Inversion height	Lower ground-level concentrations	Shorter footprint
Level of Concern (LOC):		
LOC	Smaller area exceeding LOC	Shorter footprint
Pipe or Tank Release:		
Released quantity	Larger pollutant cloud	Longer footprint
Rupture size	Faster release rate	Longer footprint
Vessel pressure	Faster release rate	Longer footprint
Vessel temperature	Faster pressurized release or puddle evaporation	Longer footprint
Evaporating Puddle:		
Puddle area	Greater evaporation rate	Longer footprint
Puddle temperature	Greater evaporation rate	Longer footprint
Air or ground temperature	Greater evaporation rate	Longer footprint
Solar radiation	Greater evaporation rate	Longer footprint
Direct Source:		
Release rate or amount	Larger pollutant cloud	Longer footprint
Release duration	Larger pollutant cloud; LOC exceeded for longer time	Longer footprint ; longer contact time
Indoor Air Infiltration:		
Air exchange rate	Faster infiltration into buildings	Faster buildup of indoor concentration and dose to higher levels

Weather and terrain

ALOHA’s footprint represents the area within which, after an accidental release, chemical concentrations may reach the Level of Concern (LOC) that you select. The degree of atmospheric turbulence influences how quickly a pollutant cloud, as it moves downwind, will mix with the air around it and be diluted below your LOC. How fast this dilution occurs affects the size of the cloud's footprint. Several weather and terrain factors substantially influence the amount of turbulence in the atmosphere, as described below.

Wind speed Although it may seem that an ALOHA footprint would be longest when the wind is strongest, the opposite is true. When the wind blows more strongly, the cloud is spread out and diluted faster, so that the area where chemical concentrations exceed your LOC is smaller. When all else is equal, lowering wind speed will increase footprint length for a given ALOHA scenario. The authors of the Green Book identified the relatively low wind speed of 3.4 miles per hour (1.5 meter per second) as the worst case wind speed. ALOHA allows you to enter a wind speed as low as 2.2 miles per hour, or 1 meter per second.

Stability ALOHA uses one of several common methods for describing atmospheric stability. In developing this method, meteorologists defined six atmospheric stability classes, ranging from class A, the least stable, to F, the most stable. The more unstable the atmosphere, the more turbulence exists, and the more rapidly a dispersing gas mixes with the air around it. When all else is equal, ALOHA will display a shorter footprint when the atmosphere is less stable, because the pollutant will be diluted more quickly to below your LOC. This is why F, the most stable class, is considered the worst-case stability class.[3]

Ground roughness Friction between the ground and air passing over it is one cause of atmospheric turbulence. Because the air nearest the ground is slowed the most, eddies develop, just as they would in the water next to a riverbank. The rougher the ground surface, the greater the ground roughness, and the greater the turbulence that develops. When all else is equal, a footprint will be longest when you choose a smaller ground roughness value. In ALOHA, the "Open Country" ground roughness category represents a smaller roughness value than the "Urban or Forest" category, and is therefore the more conservative category. However, the value that you choose for a scenario should be the one that best represents the actual average ground roughness of the area downwind of a release.

Inversion height An inversion is an atmospheric condition in which a layer of air near the ground lies beneath a very stable layer of air above. The height of the abrupt change of atmospheric stability is called the inversion height. Pollutant gases can be trapped below the inversion height. If the inversion height is low enough, ground-level concentrations of a pollutant may reach higher levels than would otherwise be expected. ALOHA accounts for the effect of an inversion only in Gaussian dispersion cases (that is, only when the escaping gas is not substantially heavier than air). In such cases, when you indicate to ALOHA that inversion height is relatively low (no greater than a few hundred feet), ALOHA accounts for the trapping of the dispersing cloud and generally predicts a longer footprint. Indicating that an inversion exists at a height greater than a few hundred feet generally will not influence ALOHA's footprint length estimate

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[3] Choosing stability class F maximizes footprint length for a given scenario. However, stability class affects not only footprint length but the degree to which the wind shifts direction. When wind direction is less predictable, the position of the footprint is also harder to predict. Wind direction is most predictable under F stability, and least predictable under A stability. Check the Jan./Feb. 1995 "Ask Dr. ALOHA" column to learn more about this.

(whether a particular inversion height is too high to affect ALOHA's footprint depends on the size of the release).

Level of Concern (LOC)
ALOHA's footprint encompasses the area in which ground-level chemical concentrations may reach or exceed your LOC. Concentrations diminish as you move away from a release point or the centerline of a pollutant cloud, so the lower the LOC, the larger the area in which it may be reached.

Evaporating puddle
Puddle area The larger the area of a puddle, the more chemical can evaporate from its surface during a given time period, and the longer ALOHA's footprint will be.

Puddle, air, and ground temperature The warmer a puddle, the more rapidly it evaporates, and, in ALOHA, the longer the resulting footprint will be. ALOHA accounts for the effects of air, ground, and initial puddle temperature on evaporation rate. In an ALOHA scenario, raising the air temperature can speed up evaporation from a puddle initially at ambient temperature, because ALOHA accounts for the degree to which heat from the air warms the puddle. Generally, the warmer the air above a puddle relative to the puddle temperature, the more the air warms the puddle, the greater the evaporation rate, and the larger the footprint. ALOHA predicts that ground temperature can substantially affect the rate of evaporation from very cold puddles, as heat from the ground warms the puddle and speeds evaporation. The greater the difference between the ground and puddle temperatures, the more important is the influence of ground temperature. The warmer the ground below a very cold puddle, the faster the evaporation rate, and the longer the footprint. The shallower the puddle, the greater the influence of air and ground temperature.

Solar radiation ALOHA accounts for the degree to which heat from the sun warms a puddle and speeds evaporation. This effect is "drowned out" by the effect of warmer ground heating a very cold puddle and raising its evaporation rate, but it can slightly affect evaporation rates from puddles at ambient temperature. Reducing cloud cover, setting time of day to midday, and setting the date to summertime rather than wintertime all increase ALOHA's estimate of the amount of solar radiation falling on a puddle.

Pipe or Tank release
Released quantity The greater the amount of chemical released from a tank or pipe, and the faster the rate of release, the longer the footprint. The amount of chemical released from a tank depends on how much chemical is stored in the tank, the pressure within the tank, the size of the hole in the tank, and its location on the tank wall. When a tank contains unpressurized liquid, ALOHA accounts for the pressure exerted by the weight of the liquid above the tank hole on the liquid below it. The greater this pressure (the more liquid above the hole), the

higher the release rate, the faster a puddle forms and spreads, and the higher the evaporation rate.

Rupture size Generally, the larger the hole in a tank or pipe, the faster the estimated release rate, and the longer the footprint. An exception is a case in which an unpressurized liquid is stored in a tank, and the hole in the tank wall is above the liquid level. In real life, only fumes will escape through the hole; ALOHA does not account for fuming of liquid in a tank.

Vessel pressure and temperature The higher the pressure within a tank or pipe, the faster the stored chemical will escape, whether it is a liquid or gas, and the longer ALOHA's footprint will be. The storage temperature of a chemical determines its physical state (gas, liquid, or solid) and the pressure within the vessel. Generally, the higher the temperature within the tank or pipe, the higher the pressure, the faster the release rate, and the longer the footprint.

Direct source

Release rate or amount Generally, the more chemical released, the longer the footprint. This is why the Green Book recommends that you use the maximum amount of the chemical that is likely to be stored in one vessel or in a series of inter-connected vessels as your release amount estimate in screening scenarios.

Release duration Increasing release duration for a Direct release can lengthen the footprint if the initial duration is relatively brief. Increasing duration also increases the length of time that the LOC is predicted to be exceeded. Generally, the longer people are in contact with a hazardous gas, the more serious the hazard.

Indoor air infiltration

Air exchange rate The faster the air exchange rate for a building, the more rapidly a pollutant gas infiltrates into the building. Concentrations of gas build up more rapidly to higher levels within the building, increasing ALOHA's estimates of maximum indoor concentration and dose. Check ALOHA's Text Summary screen or Concentration by Time graph for a location of concern to see this effect. Air exchange rate is higher for unsheltered than sheltered buildings, and for single-storied than double-storied buildings.

Remember...

When you design an ALOHA scenario, if you don't have an exact value for a key model input such as wind speed or tank hole size, consider whether the value you're thinking of using is more likely to be conservative (likely to make the footprint longer) or nonconservative (likely to make the footprint shorter). By doing so, you can make your scenario as conservative as you wish.

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